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ABSTRACT

Described is an analysis of the content, tasks, and strategies needed by students to enable them to identify insects to order by sight and to family by use of a standard dichotomous taxonomic key. Tasks and strategies are broken down and arranged progressively in the approximate order in which students should progress. Included are listings of insect identification variables, a network of identification procedures for each variable, a flow-chart utilizing five variables for ordering insects into 14 "order sets," and characteristic charts of variables for 22 orders of insects. (SI)

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A TASK-CONTENT ANALYSIS OF AN INTRODUCTORY ENTOMOLOGY CURRICULUM

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BEST COPY AVAILABLE

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INTRODUCTION

The usual, beginning Entomology Lab is a course where students in the Biological Sciences (Zoology, Botany, Forestry, Entomoly, etc) are first introduced to insects and the procedures for identifying them. At Michigan State the lab is designed to run concurrently with a lecture course dealing with the basics of insect physiology, taxonomy and evolutionary development. The lab course is primarily intended to teach the student to identify the 20-25 major Orders of insects, and to key various members of these Orders down to Family level.

This analysis deals with the curriculum design for a college level, introductory Entomology systematic laboratory. The "terminal objective" of the course, as defined for this analysis, is to have students identify insects to Order by sight inspection, and to Family by inspection and a minimum use of a standard dichotomous taxonomic key. The "classical" course which has students examine insects until they are "familiar with the key" often fails or is inefficient due to the students' inability to correctly identify insect variables and consequently develop strategies to complete the terminal task. The objective of this analysis is to identify the assumptions and knowledge components underlying the lab course. Once identified, assumptions and components may be re-examined and the course curriculum altered or restructured for greater efficiency in teaching students skills and strategies for completion of the terminal task.

The actual, step by step, methods employed in this analysis are not discussed in detail in this paper. The interested reader is referred to Smith's (1974) article on "Techniques for Instructional Design", for a detailed discussion of methods in Task-Content Analysis.

Analysis of this type usually requires the generation of a number of analytical tools - charts, matrices, tables, etc. Several of the analytical devices generated in this analysis are in fact prototypes of teaching and learning aids which may be useful in any restructured lab curriculum.

CONTENT ANALYSIS

The first step was to examine the subject content of the Entomology lab. Normally students are taught to identify insects by examining taxonomic characteristics which are often related to insect evolution. The student begins by examining a simple, primitively wingless Order such as the Collembola and progresses to the most advanced order, the Hymenoptera, picking up identifying characteristics along the way. After gaining familiarity with the insect world in this way the student could then use a chart such as the one shown in Figure 1 to classify an insect to Order. However, the important taxonomic characteristics are often confusing and misleading to the novice student. I will assume for this analysis that the prime purpose of the course is to develop the practical ability to identify insects, and that the evolutionary relevance of various taxonomic characters will be covered elsewhere (preferably after the student knows which insects are which).

With this in mind, 26 variables were identified from Figure 1 to be of use in practical insect classification to the Order level. These variables are listed in Table 1. For each variable, the elements, a definition of the values, and an observational procedure were identified using the Smith model (1973). This Analytic/Systemic Network is shown in Table 2. Three variables, male and female characters and general appearance, have been deleted from Table 2, because they are useful

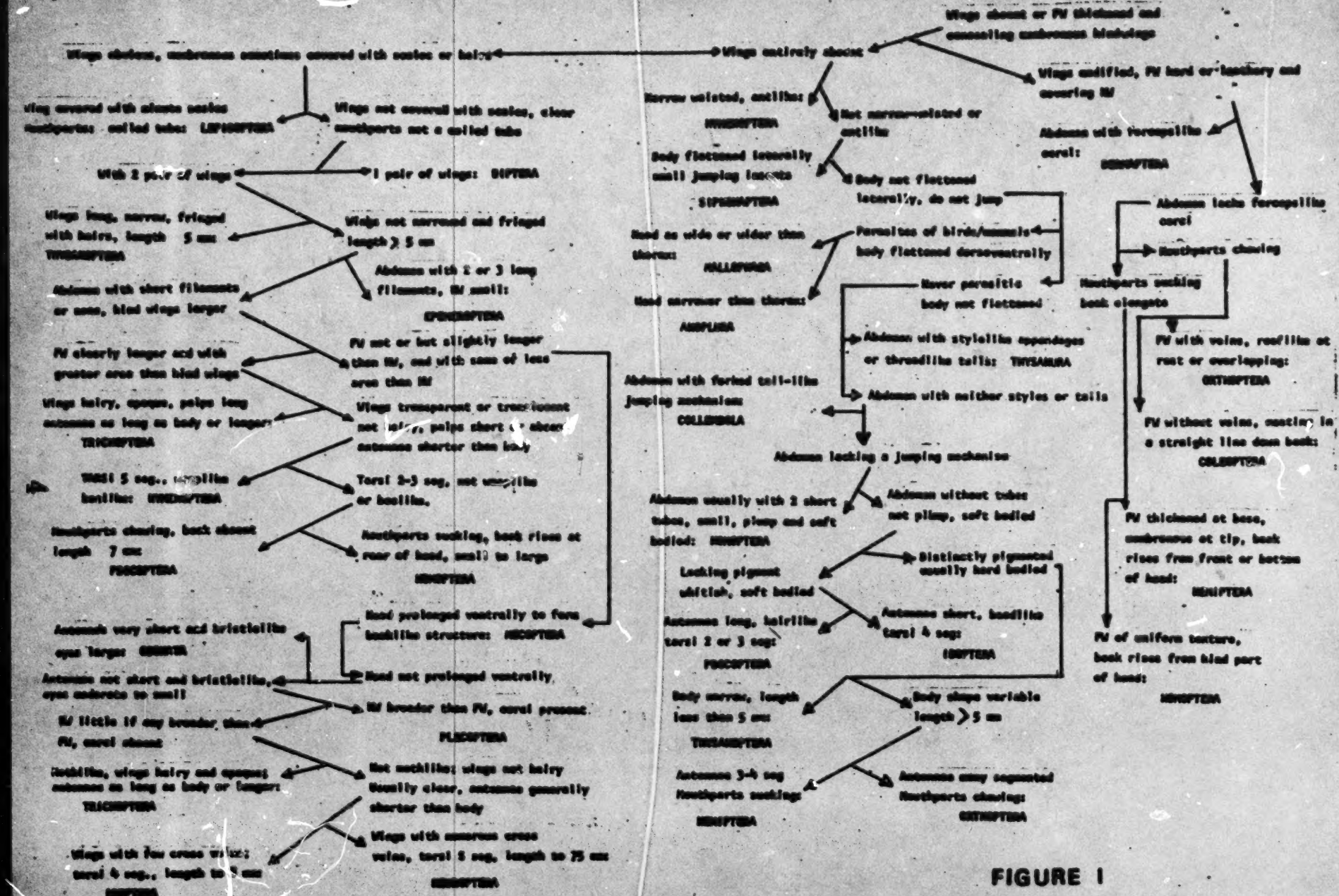
Wings absent, membranous sometimes covered with scales or hairs
Wings entirely absent
Wings absent or FW thickened and concealing membranous hindwings
Wings modified, FW hard or leathery and covering HW
Abdomen with forcepslike cerci: DERMAPTERA
Wing covered with minute scales
Mouthparts: coiled tube: LEPIDOPTERA
Wings not covered with scales, clear
Mouthparts not a coiled tube
With 2 pair of wings
1 pair of wings: DIPTERA
Narrow waisted, antlike: HYMENOPTERA
Not narrow-waisted or antlike
Body flattened laterally
small jumping insects: SIPHONAPTERA
Body not flattened laterally, do not jump
Parasites of birds/mammals
body flattened dorsoventrally
Head as wide or wider than thorax: MALLOPHAGA
Head narrower than thorax: ANOPLURA
Never parasitic
body not flattened
Abdomen with stylelike appendages or threadlike tails: THYSANURA
Abdomen with neither styles or tails
Abdomen lacks forcepslike cerci
Mouthparts chewing
Mouthparts sucking
beak elongate
FW with veins, resilike at rest or overlapping: ORTHOPTERA
FW without veins, meeting in a straight line down back: COLEOPTERA
FW thickened at base, membranous at tip, beak rises from front or bottom of head: HEMIPTERA
FW of uniform texture, beak rises from hind part of head: HOMOPTERA
Abdomen with forked tail-like jumping mechanism: COLLEMBOLA
Abdomen lacking a jumping mechanism
Abdomen usually with 2 short tubes, small, plump and soft bodied: HOMOPTERA
Abdomen without tubes not plump, soft bodied
Lacking pigment whitish, soft bodied
Antennae long, hairlike
tarsi 2 or 3 seg: PSOCOPTERA
Distinctly pigmented usually hard bodied
Antennae short, beadlike
tarsi 4 seg: ISOPTERA
Body narrow, length less than 5 mm: THYSANOPTERA
Body shape variable length > 5 mm
Antennae 3-4 seg
Mouthparts sucking: HEMIPTERA
Antennae many segmented
Mouthparts chewing: ORTHOPTERA
Wings with numerous cross veins, tarsi 5 seg, length to 75 mm: HEMIPTERA
Wings with few cross veins: tarsi 4 seg., length to 5 mm: ISOPTERA
Hindwing much larger than FW, anal area fanlike when at rest: PLECOPTERA
Hindwing little if any broader than FW, anal absent
Antennae very short and bristlelike
eyes large: ODONATA
Antennae not short and bristlelike, eyes moderate to small
Head not prolonged ventrally
Head prolonged ventrally to form beaklike structure: MECOPTERA
Mouthparts chewing, beak absent length 7 mm: PSOCOPTERA
Mouthparts sucking, beak rises at rear of head, small to large: HOMOPTERA
Tarsi 5 seg., threadlike or beadlike: EMBIOPTERA
Tarsi 3-5 seg, not threadlike or beadlike.
Wings hairy, opaque, palps long antennae as long as body or longer: TRICHOPTERA
Wings transparent or translucent not hairy, palps short or absent antennae shorter than body
Abdomen with short filaments or none, hind wings longer
FW clearly longer and with greater area than hind wings
Wings long, narrow, fringed with hairs, length 5 mm: THYSANOPTERA
Wings not narrowed and fringed length > 5 mm
Abdomen with 2 or 3 long filaments, HW small: EPHEMEROPTERA
FW not or but slightly longer than HW, and with same or less area than HW

FIGURE 1

(from Borror and White
A Field Guide to the Insects)

TABLE 1

VARIABLES

Number of Wings
Fore Wing Description
Hind Wing Description
Fore wing - Hind wing Size Ratio
Wing Position at rest
Body Size
Body Shape
Body Hardness
Body Pigment
Mouthparts
Mouthpart Location
Palps
Head Characteristics
Thorax
Abdominal Segments
Abdominal Shape
Abdominal Appendages
Compound Eye Size
Compound Eyes-Relative Position
Antennae Type
Antennae Length
Leg Characteristics
Tarsi
Male Characteristics
Female Characteristics
General Appearance

TABLE 2

ANALYTIC NETWORK / VARIABLE	SYSTEMIC NETWORK: Number of Wings (Wing Pr.)	Wing Description	Wing Position at Rest	Body Size	Body Shape
ELEMENTS	Insect Wings	Insect Wings	Insect Wings	Insect Bodies	Insect Bodies
DEFINITION	Number of Wings Present on Thorax	Appearance of Wings	Natural Resting Position of Insect's Wings	Physical Size Relative to some "general" insect size	Physical Shape of Body
VALUES	0, 2, 4 (0, 1, 2 pr.)	Membranous, leathery, scaled, hairy, elongate, large, triangular, thickened, long, narrow, fringed, meet in straight line, cross veins, few veins, many veins, reduced venation.	Overbody, flat over abdomen, never folded, rooflike, outstretched upward/outward, folded fanwise, overlapping	Minute, small, medium, large, giant (0.1mm-50cm)	Elongate, oval, long, stout, thin, flattened
OBS. PRO.	Count	Observe with eye (hand lens/stereo microscope)	Observe wing position on resting or dead insect	Observe and compare to "standard" (measure length)	Observe

TABLE 2
(Continued)

ANALYTIC NETWORK	SYSTEMIC NETWORK						
VARIABLE	Body Hardness	Body Pigment	Mouthparts	Palps	Head Character	Thorax	Abdominal Segments
ELEMENTS	Insect Bodies	Insect Bodies	Insect Mouthparts	Insect's maxillary or labial palps	Insect Heads	Insect Thoraxes	Abdominal Segments
DEFINITION	Apparent hardness of exoskeleton	Amount darkening pigment present. Insect's coloring	Type of eating apparatus present	Degree of development of mouthpart appendages	Dominant character of head	Obvious character of insect's thorax	Number of apparent segments composing the abdomen
VALUES	Soft, medium soft, hard, extremely hard	Pale, white, dark,	Chewing, sucking, vestigial, rasping, sponging	Lacking, developed, well developed	No eyes, mostly eyes, face bulging, long faced, wider, narrower than thorax	Robust, gill remnants	4, 5, 6, 7, 8 9, 10, 11, ...
OBS. PRO.	Feel body	Observe color/ darkness of insect	Observe with a hand lens or stereo microscope	Observe with a hand lens or stereo microscope	Observe insect's head	Observe insect's thorax	Count apparent abdominal segments

TABLE 2
(Continued)

ANALYTIC NETWORK	SYSTEMIC NETWORK					
VARIABLE	Abdominal Shape	Abdominal Appendages	Compound Eye Size	Compound Eyes Relative Position	Antennae Type (Segments)	Antennae Length
ELEMENTS	Insect Abdomens	Appendages of Insect Abdomens	Insect's Compound Eyes	Insect's Compound Eyes	Insect Antennae	Insect Antennae
DEFINITION	Apparent shape of the abdomen	Type (and number) of conspicuous abdominal appendages	Relative size of compound eyes	Relative position of the two compound eyes on the head	Physical appearance of antennae, including number and shape of segments	Physical length of extended antennae relative to body length
VALUES	Long, thin tapering, fat	None (0), male genitalia, caudal filament(s), cerci, furcula, collophore, small claspers forcepslike cerci (1,2,3)	Absent, small medium, large	[illegible]y separated early touching	Small, short, bristlelike, beadlike, tapering, distally, pectinate, clubbed, knobbed, plumose, variable, 3-12 segmented	Long, short, absent, $\frac{1}{2}$ body length, as long as body, longer than body, concealed, conspicuous
OBS. PRO.	Observe the abdomen	Observe and count the abdominal appendages	Observe compound eyes	Observe compound eyes	Observe antennae (hand lens, stereo microscope) and count segments	Observe antennae

TABLE 2
(Continued)

ANALYTIC NETWORK	SYSTEMIC NETWORK			
VARIABLE	Leg Characteristics	Tarsi	Order Set	
ELEMENTS	Insect Legs	Tarsal portion of leg (foot)	Insect Orders	
DEFINITION	Physical characteristics of legs	Number of apparent tarsal segments	Groups of orders, naturally grouped by certain characteristics	
VALUES	Large, jumping short, long slender, large coxae, 1 large claw, 1-2 claws	1 - 5	$S_1 - S_{14}$	
OBS. PRO.	Observe legs	Observe and count tarsal segments	Determined by inspection	

only as supplementary verifiers. "Order Sets" has been added to the Variables in Table 2 and will be discussed below.

Two identification divices were also developed from the 26 variables. The Flow Chart, shown in Figure 2, uses only five variables (number of wings, wing description, mouthparts, body flattening and body hardness) to classify the insect to "Order Set". The Order Sets, which are not mutually exclusive, are listed in Table 3. The Flow Chart basically outlines a simple strategy for identification to a level intermediate between Class and Order.

The Characteristics Chart is shown in Table 4. The Values for each of the 26 variables are listed for each of the 22* Orders of interest. This Chart serves as a separator, eliminator or verifier when moving from the Order Set level to the Order level.

TASK GENERATION: THE VARIABLE VALUE NETWORK

By examining Smith's "Tasks for the Variable-Value Network" (1973), eleven tasks were found that are relevant to the variables involved and the goals fo the analysis. These tasks are described in the left hand column of Table 5. Table 5 also shows the Task-Content Matrix, formed by crossing the eleven tasks with the twenty-three variables.** The tasks are arranged with the simplest at the top, and the most complex at the bottom. Each row x column cell in the matrix represents a particular task performed on a particular variable. Sample tasks on particular variables have been described in many of the cells. The last four tasks are more complex and involve more than one variable. For example, the Directed Coordinated Sorting Task (Example 9) is performed on the variables Wing Descritpion and Mouth Parts (9's appear in the appropriate cells).

The arrangement of simple to complex tasks indicates the approximate order in which the students would progress in order to achieve the desired familiarity with the variables before attempting to classify an insect. The area blocked out in the lower right corner of the Task-Content Matrix indicates that performing the corresponding tasks on the variable adds nothing to learning how to identify insects (the combinations of those variables have no relevance to insect identification). The complex task end of the Matrix (the last four tasks) provides experience sorting on those five variables used in the Flow Chart.

THE CLASS MEMBER NETWORK

The Task-Variable manipulations provide practice in dealing and a familiarity with the variables but do not lead logically to a concluding task in which the student must classify insects to Order. It became evident during the course of the analysis that a Class Member Network must somehow be coupled to the complex-task end of the Variable-Value network. Examining Smith's "Tasks for the Class Member Network" (1973), nine tasks were identified as useful in developing the classification skills and strategies needed here. These tasks are listed on the left side of Table 6, by order of increasing complexity from top to bottom. The ninth task, listed at the bottom of Table 6 is the "classification with only supplementary aid" task that was defined as a goal for the curriculum.

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*ORDERS: Protura, Diplura, Embioptera, Zoraptera, and Strepsiptesa have been eliminated from the Analysis because of their relative rarity.

**Not all variables are shown in order to conserve space.

FLOW CHART

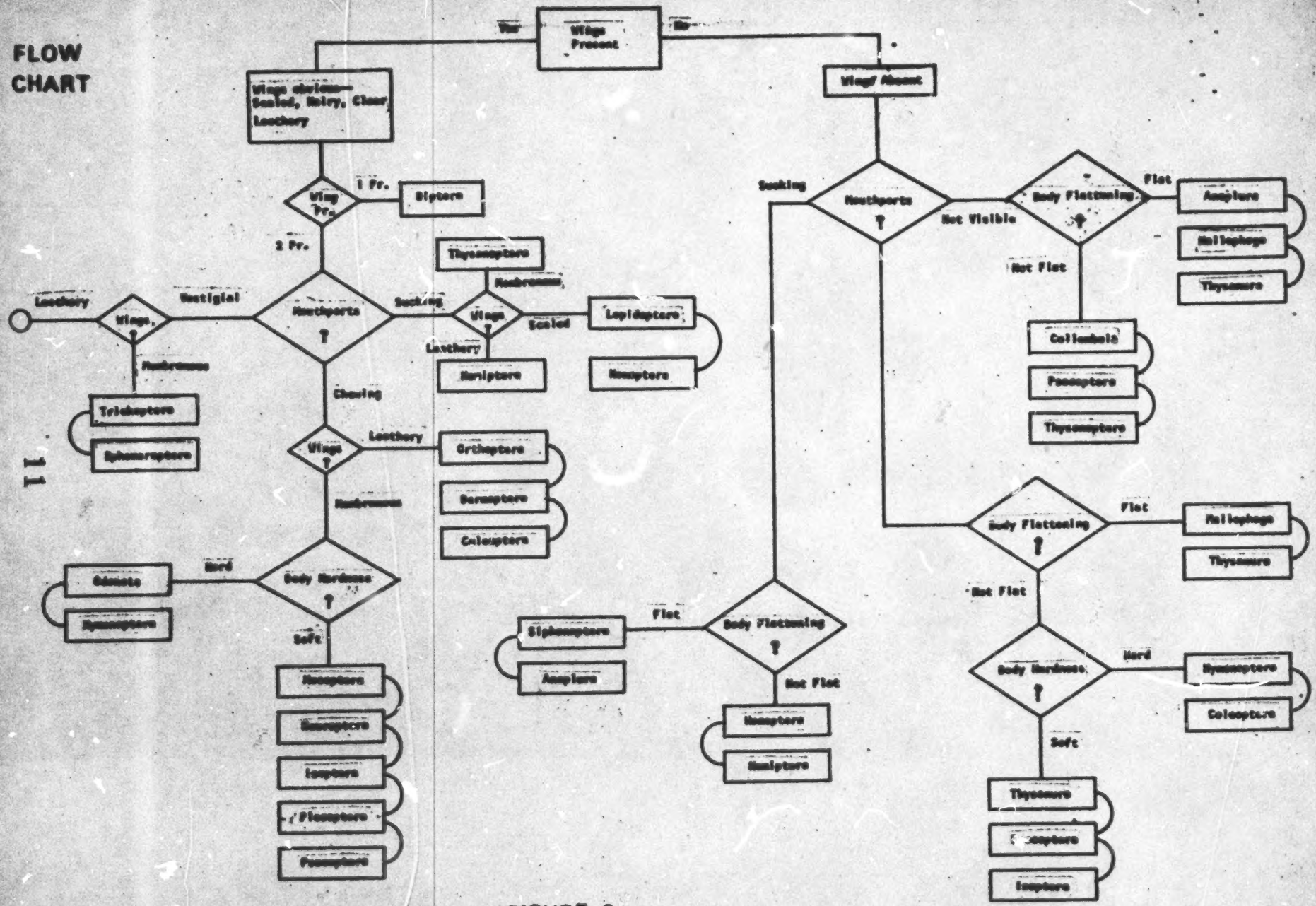

FIGURE 2

TABLE 3

Order Sets

S_1	Diptera
S_2	Trichoptera, Ephemeroptera
S_3	Odonata, Hymenoptera
S_4	Mecoptera, Neuroptera, Isoptera, Plecoptera, Psocoptera
S_5	Thysanoptera
S_6	Lepidoptera
S_7	Hemiptera, Homoptera
S_8	Orthoptera, Dermaptera, Coleoptera
S_9	Siphonaptera, Anoplura
S_{10}	Mallophaga, Thysanura
S_{11}	Thysanura, Psocoptera, Isoptera
S_{12}	Hymenoptera, Orthoptera
S_{13}	Collembola, Psocoptera, Thysanoptera
S_{14}	Anoplura, Mallophaga, Thysanura

TABLE 5

TASKS \ VARIABLES	NUMBER OF WINGS	WING DESCRIPTION	MOUTHPARTS
Similarity Subset Formation Given: variable name, an array of elements differing on that variable, comp. val. "same" Indicate a subset of elements which are the same on the named variable.		**Similarity Subset Formation:** **Example** Given an array of insects differing on size, color and wing description. Pick out those which have the same type of wing	
Directed Comparison Given: Variable name, an array of elements Produce the comparative value (same, not same)			**Directed Comparison: Example** Given: A set of insects Compare the mouthparts of the insects in the set
Ordinal Discrimination Given two elements and an ordinal value identifying the variable Indicate the element to which the ordinal value applies.			
Directed Seriation Given: An array of elements, A variable name Indicate the order of the elements on the named variable			
Directed Sorting Given a variable name, an array of elements Indicate subsets of elements which are similar on the variable		**Directed Sorting: Example** Given a set of wings, Variable = wings Indicate subsets of elements which are similar on wing description	
Sorting Variable Identification Given subsets of elements each similar on a variable, Produce the name of the variable	**Sorting Variable Identification: Example** Given subsets of insects grouped according to the number of wings they have Name the sorting variable	—	
Nondirected Sorting Given an array of elements Indicate subsets of elements similar on a single variable		**Nondirected Sorting: Example 7** Given a set of insects differing on wing description, number of abdominal appendages and body hardness. Place the insects so that each group is the same in some way	
Subset Division Given an array of elements sorted into subsets on a variable, the name of another variable, indicate within each subset, subsets which are similar on the named variable.		8	**Subset Division: Example 8** Given subsets of insects sorted by wing description Subdivide the groups by the types of mouthparts they have
Directed Coordinated Sorting Given an array of elements, two variable names, Indicate sets of elements similar on one variable and within each set, subsets similar on the other variable		9	**Directed Coordinated Sorting** **Example 9** Given an array of insects sort first on mouthparts then on wing description
Partially Directed Sorting Given an array of elements, and a variable name, Indicate sets similar on the named variable and within each set, subsets similar on another variable			10
Nondirected Sorting Given: An array of elements Indicate sets which are similar on a variable and within each set, subsets similar on a different variable		11	**Nondirected Sorting: Example 11** Given a set of insects differing on wing description, mouthparts, and body hardness Indicate sets similar on one variable, and within each set subsets similar on a different variable

The Variable Value Tasks "Partially Directed Sorting" and "Non-directed Sorting" tend to overlap with the Class Member Tasks "Directed Partitioning" and "Directed Hierarchical Classification". This overlap is present to provide a smooth transition from the Variable-Value Network to the Class-Member Network.

Table 6 also lists an example for each task and presents a strategy by which to accomplish the task. The Flow Chart and Characteristics Chart are introduced individually as tools within a strategy at first. As the tasks become more complex, they are used in tandem. Further on the strategies induce the use of Long Term memory of the Flow Chart and Characteristics Charts first separately, and then together. The final task requires the classification of an insect to Order using the Long Term Memory of the Flow Chart and Characteristics Charts as a guide.

Figure 3 illustrates the flow of tasks from the initial simple variable-value tasks to the final classification task.

CURRICULUM GENERATION

The analysis has provided a course content, a linked-series of tasks, strategies and tools used in the strategies. Now it remains to develop a course from all of this. The procedure involved is fairly straight-forward. One begins by acquainting the student with the variety of variables he will be dealing with using, perhaps, a form similar to Table 2. The simple variable-value tasks are then performed; not necessarily repeating each task with all 23 variables, but using a wide enough scope so that the student gains a familiarity with all of the variables. As the variable-value tasks become more complex, using several variables, concentration should be focused on the first 5 variables of Table 5, in preparation for performing the Class Member Tasks and using the Flow Chart. As the student reaches the 3rd or 4th task in the Class Member Network, he has all the necessary variable identification skills (without getting "hung up" on the value of a variable). With increasing practice the last few Class Member tasks tend to cascade toward the final classification task.

The methods of teaching or implementing these tasks are of course not readily defined. The early, simple variable-value tasks might easily lend themselves to the auto-tutorial mode, so that the initial familiarization with the variables proceeds quickly and efficiently. The later tasks must be performed with insect specimens and stereo-microscopes or hand lenses in the usual manner. Even though this analysis and curriculum puts a premium on practical methods of identification, experience is still necessary to develop skills in classification.

The same analytical procedure can again be used to develop the curriculum further; classifying from the Order level to the Family level. The variables would have to be revised to reflect the relevant classification characters of the particular Orders involved, but the same Variable Value tasks could be used again. (For the Order Coleoptera, one could use such variables as notopleural sutures, and state of the coxial cavity to move toward the Family level). The Flow and Characteristics Charts could be revised to reflect differences in Family Sets and Families respectively, but the Class Member Tasks and Strategies would remain unchanged. Moving from the Class-to-Order classification curriculum outlined in this paper to the Order-to-Family classification curriculum briefly sketched above would hopefully entail considerable learning strategy transfer. A student most likely would develop considerable

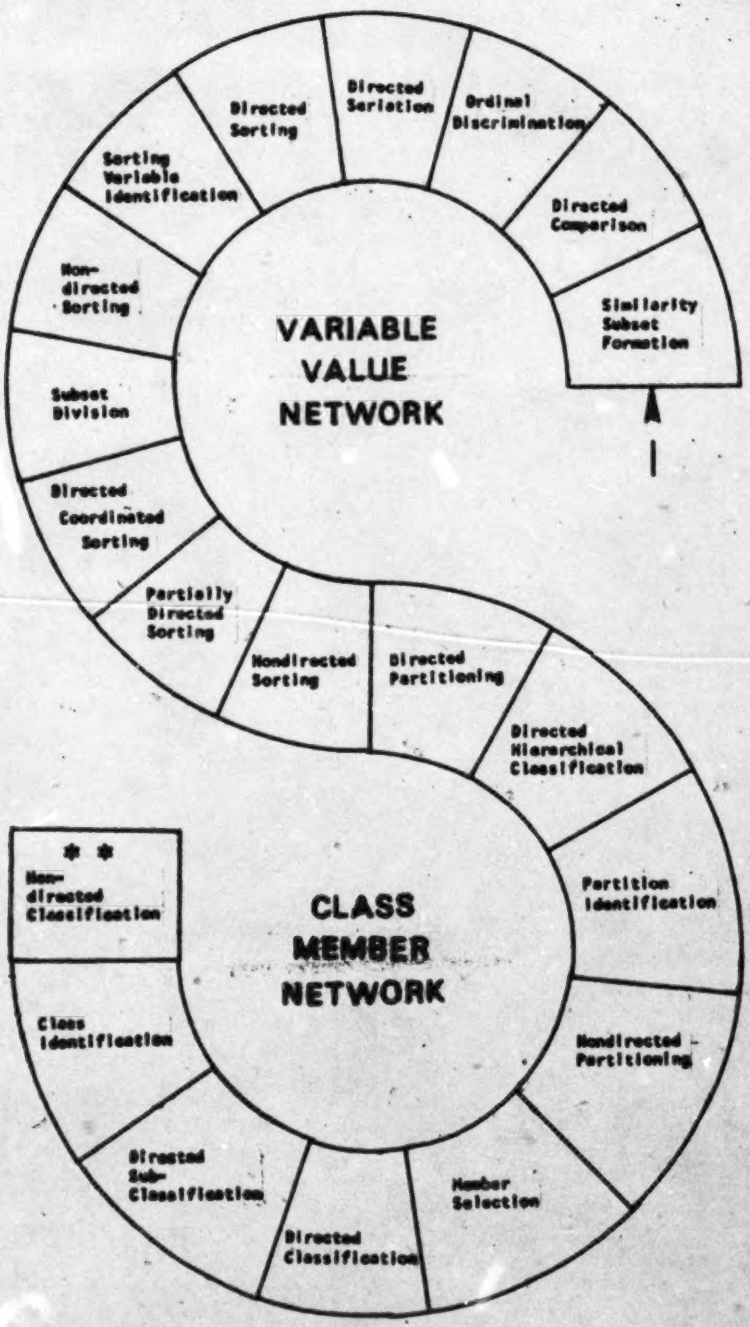
VARIABLE VALUE NETWORK
Directed Sorting
Directed Seriation
Ordinal Discrimination
Directed Comparison
Similarity Subset Formation
Sorting Variable Identification
Non-directed Sorting
Subset Division
Directed Coordinated Sorting
Partially Directed Sorting
Nondirected Sorting
Directed Partitioning
Directed Hierarchical Classification
Partition Identification
Nondirected Partitioning
Member Selection
Directed Classification
Directed Sub-Classification
Class Identification
Non-directed Classification
CLASS MEMBER NETWORK

FIGURE 3

skill in classifying after using these Variable-Task-Strategy combinations several times.

ANALYTICAL DISCONTINUITIES

This analysis violates one of the axioms of the task content method. The Class Member Network requires that a Superordinate class be partitioned into mutually exclusive classes. For the present case the Superordinate class is the "Class Insecta", which is partitioned into the 22 separate Orders. However, the addition of the partition "Order Sets" to aid in the development of the Classification Strategies violates this tenet. The Order Sets are not mutually exclusive, due simply to the wide variation in 1.5 million insect species. The Order Sets do serve the purpose of breaking the 22 Orders down to groups of between one and five members, which can be handled more efficiently by the human information processing mechanism. Treating the Order Sets as a Variable rather than as a partition "bends" the analytical method a bit but does not destroy the validity of the analysis. Thinking of Order Sets as a transition factor between the Variable-Value Network and the Class Member Network rectifies the discontinuity and allows a smooth transition.

FUTURE POSSIBILITIES

When working with this type of analysis it is easy to get a "feel" for the proper sequencing of tasks and strategies upon the content. Whether or not this intuitive sequencing is the most efficient in promoting learning is questionable. It does appear, however, that there may be a procedure where mathematical relationships could be developed for the tasks, content and strategies in terms of learning efficiency, transfer, skill development, etc. After assignment of these functions, one could optimize the task selection and sequence for the various parameters (efficiency, transfer, etc.) based on certain boundary conditions (cost, time, facilities, etc.). An optimum curriculum based on all available data would be the result. Currently, we are searching for just such a procedure.

The result of this analysis is a complete breakdown of the content, tasks, and strategies for the mastery of the complex terminal classification objective. These parts are all laid out and ready to be assembled into a curriculum by a competent developer, who may choose to omit some components and emphasize other in any number of possible combinations. However, regardless of the curriculum format, any ambiguity as to the underlying structure has been minimized by this analysis. The analysis provides a range of alternatives for use in revision or research.

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BODY FLATTENING	BODY HARDNESS	WING POSITION AT REST	BODY SIZE
		Given a set of insects Compare the positions of the wings at rest	
	Ordinal Discrimination: Example Given two insects, identify which has the harder body		
			Directed Seriation: Example Given a set of insects, Variable = size Order the insects on size
Directed Sorting: Example Given a set of insects, indicate subsets similar on body flattening			
		Sorting Variable Identification Example Given subsets of insects grouped according to their wing position at rest Name the sorting variable	
	7		
Partially Directed Sorting Example 10 Given a set of insects differing on mouthparts, body flattening and body hardness sort on mouthparts, then sort further on another variable	10		
	11		

MOUTHPART LOCATION	PALPS	ABDOMINAL SEGMENTS	ABDOMINAL APPENDAGES
	Given a set of insect (heads) Compare the palps of the insects in the set		Given a set of insects Compare the abdominal appendages of the insects in the set
		Given a set of insects Variable = Number of abdominal segments Order the insects on number of abdominal segments	
Directed Sorting: Example Given a set of insects Indicate subsets similar on mouthpart location.			
			7

COMPOUND EYE SIZE	ANTENNAE TYPE	ANTENNAE LENGTH	TARSAL SEGMENTS
	Given an array of insects differing on several variables Pick out those which have the same type of antennae		
			Given two insects identify which has the greatest number of tarsal segments
Given a set of insects Variable = Compound eye size Order the insects on compound eye size			

TABLE 6

CLASS-MEMBER NETWORK

TASK	TASK EXAMPLE	STRATEGY	
Directed Partitioning: Given an array of elements and a partition name, indicate which elements are members of the same subclasses	**Directed Partitioning: Example** Given a set of insects, sort them by the kind of mouthparts they possess (chewing, sucking, vestigial)	**Strategy:** Developed in task sequence in variable - value section	
Directed Hierarchical Classification Given a set of elements belonging to a superordinate class and the names of a partition and subpartition, indicate membership of elements in classes of the subpartition, and inclusion of these classes in classes of the partition	**Directed Hierarchical Classification, Example:** Given a set of insects, Classify by wing and mouthparts	**Strategy:** Developed in task sequence in variable - value section	
Partition Identification Given subsets of elements sorted by classes of a partition, produce the names of the partition and/or names of the classes	**Partition Identification: Example** Given insects belonging to several order sets, indicate how the insects have been grouped.	**Strategy:** Examine insects using the flow chart to order set as a guide.	
Undirected Partitioning Given a set of elements belonging to subclasses of a partition, indicate which elements are members of the same subclasses	**Undirected Partitioning: Example** Given a set of wingless insects indicate which belong to the same order set.	**Strategy:** Examine insects using the flow chart to order set as a guide.	**Strategy:** Examine the insect using L.T. Memory of the Flow chart.
Member Selection Given an array of elements and a class name, indicate which elements are members of the class.	**Member Selection: Example** Given an array of insects class name = Insectera, indicate which of the insects are members of the class (order) Insectera	**Strategy:** Examine insects using variables in characteristics chart as a guide	
Directed Classification Given an element (member of a class) and the name of a partition including that class, produce the class name	**Directed Classification: Example** Given an insect, Partition name = Order Set 13 (Collembola, Pterygota, Thysanoptera) Indicate the order to which this insect belongs	**Strategy:** Examine the insect using variables in characteristics chart as a guide.	**Strategy:** Examine the insect using L.T. Memory of variables in characteristics chart as a guide. Classify on those variables.
Directed Subclassification, Given subsets of elements belonging to different classes of a partition and the name of a subordinate partition, indicate the membership in subclasses of each class	**Directed Subclassification:** Example Given insects sorted by order set, sort to order	**Strategy:** Examine the insect using variables in characteristics chart as a guide.	**Strategy:** Examine insects using L.T. Memory of variables in characteristics chart as a guide. Classify to order on those variables.
Class Identification Given a set of elements, all of which are members of the same class, produce the name of the class	**Class Identification: Example** Given samples of Grasshoppers, Mantids, cockroaches, walking sticks and crickets, indicate the order to which they all belong.	**Strategy:** Examine insects using L.T. Memory of variables in characteristics chart as a guide. Classify to order on those variables.	
Undirected Classification Given an element which is a member of a class, produce the class name	**Undirected Classification:** Example: Given an insect Classify the insect to the order set level	**Strategy:** Semi-Directed Sorting Given the insect, indicate the set, subset, subsubset, etc. to which it belongs, until the order set level is reached, using the flow chart as a guide.	**Strategy:** Internally Directed Sorting Given the insect, generate a list of sequential variables to sort on from L.T. Memory of the flow chart. Use these variables to classify to the order set level.
	Undirected Classification: Example: Given an insect Classify the insect to the Order level	**Strategy** Semi-Directed Sorting Given the insect, indicate the set, subset, subsubset etc. to which it belongs until the order set level is reached, using the flowchart as a guide. Then identify the specific order to which it belongs using the characteristics chart.	**Strategy:** Semi-Internally Directed Sorting Given the insect, indicate the order set to which it belongs using L.T. Memory of the Flow chart. Then identify the specific order to which it belongs using the characteristics chart.
		Strategy: Internally Directed Sorting Given the insect, indicate the order set to which it belongs using L.T. Memory of the flow chart. Then identify the specific order to which it belongs using L.T. Memory of characters from the characteristics chart.	

TABLE 4

CHARACTERISTICS CHART

COLLEMBOLA	
Number of Wings	0
FW Description	-
HW Description	-
FW/HW	-
Wing pos. at rest	-
Body Size	Minute
Body Shape	Elongate, Oval
Body Hardness	Soft
Body Pigment	-
Mouthparts	Chewing
Mouthpart Location	H
Palps	-
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	Furcula, collophore
comp. eye size	Small
comp. eye-rel. pos.	-
Antennae Type	4-6 Seg.
Antennae Length	Short
Leg Characteristics	-
Tarsi	-
Characters ♀	-
General Appearance	Very small
Common Name	Snowfleas

EMPHEMEROPTERA

Number of wings	4
FW Description	large, triangular, many veined
HW Description	small, rounded
FW/HW	-
Wing pos. at rest	together, above body
Body Size	Small-Medium
Body Shape	Elongate
Body Hardness	Soft
Body Pigment	-
Mouthparts	Vestigial
Mouthpart Location	H
Palps	-
Head Characteristics	-
Abdominal Shape	Long
Abdominal appendages	2-3 Hairlike tails
Comp. eye size	-
Comp. eye-Rel. Pos.	-
Antennae Type	Small, bristlelike
Antennae Length	Short
Leg Characteristics	-
Tarsi	3-5 seg
Characters ♀	-
General Appearance	Fragile bodied, fluttering insects
Common Name	Mayflies

THYSANURA	
Number of Wings	0
FW Description	-
HW Description	-
FW/HW	-
Wing pos. at rest	-
Body Size	Medium
Body Shape	Elongate, Oval
Body Hardness	Soft
Body Pigment	Grey Brown
Mouthparts	Chewing
Mouthpart Location	H
Palps	-
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	2 cerci, 1 caudal filiment
Comp. eye size	small-large
Comp. eye-rel. pos.	widely seperated or touching
Antennae Type	Many segmented
Antennae Length	Long
Leg Characteristics	-
Tarsi	-
Characters ♀	-
General Appearance	Scaled
Common Name	Silverfish

ODONATA-ANISOPTERA	
Number of Wings	4
FW Description	Elongate, Membranous, many veined
HW Description	same
FW/HW	HW broader at base
Wing Pos. at rest	outstretched
Body Size	Large
Body Shape	long, stout
Body Hardness	hard
Body Pigment	-
Mouthparts	chewing
Mouthpart Location	H
Palps	-
Head Characteristics	Mostly eye
Abdominal Shape	Long, thin
Abdominal Appendages	Small, claspers
Comp. eye size	Large
Comp. rel. pos.	Nearly touching
Antennae Type	Short, bristlelike
Antennae Length	Short
Leg Characteristics	-
Tarsi	-
Characters	Ovipositor
General Appearance ♀	Robust, large, darting
Common Name	Dragonfly

ODONATA-ZYGOPTERA	
Number of Wings	4
FW Description	elongate, membranous, many veined
HW Description	same
FW/HW	1
Wing Pos. at rest	above body
Body Size	Medium
Body Shape	Thin
Body Hardness	Hard
Body Pigment	-
Mouthparts	chewing
Mouthpart Location	H
Palps	-
Head Characteristics	mostly eye
Abdominal Shape	thin
Abdominal Appendages	-
Comp. eye size	large
Comp. eye-rel. pos.	nearly touching
Antennae Type	bristle-like
Antennae Length	short
Leg Characteristics	-
Tarsi	-
Characters ♀	-
General Appearance	Fragil, fluttering, thin bodied
Common Name	damselfly

ORTHOPTERA	
Number of Wings	4,0
FW Description	long, narrow, thick veined
HW Description	membranous, broad veined
FW/HW	-
Wing Pos. at rest	HW folded fanlike
Body Size	large
Body Shape	
Body Hardness	Hard
Body Pigment	-
Mouthparts	Chewing
Mouthpart Location	H
Palps	-
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	cerci, short or long
Comp. Eye Size	large
Comp. eye rel. pos.	-
Antennae Type	hairlike
Antennae Length	short, long
Leg Characteristics	large jumping hind legs
Tarsi	3-5 seg.
Characters ♀	ovipositor
General Appearance	large, jumping, walking, insects
Common Name	crickets, grasshoppers, mantids, walkingsticks

ISOPTERA	
Number of Wings	4,0
FW Description	long, narrow, weakly veined
HW Description	~ FW
FW/HW	1
Wing Pos. at rest	Flat over abdomen
Body Size	small
Body Shape	-
Body Hardness	soft
Body Pigment	pale
Mouthparts	chewing
Mouthpart Location	H
Palps	Developed
Head Characteristics	No eyes in unwinged forms
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Small
Comp. eye-Rel. Pos.	-
Antennae Type	Thread or bead like
Antennae Length	Short
Leg Characteristics	-
Tarsi	-
Characters ♀	-
Gen. Appearance	Soft bodied, light colored (society) insects
Common Name	Termites

PLECOPTERA

Number of Wings	4
FW-Description	Long, Narrow, Many veined membranous
HW Description	HW shorter, many veined large anal lobe
FW/HW	FW < HW
Wing Pos. at Rest	Flat over abd., Anal lobe folded fanlike
Body Size	Medium
Body Shape	Elongate, flattened
Body Hardness	Soft
Body Pigment	-
Mouthparts	Chewing
Mouthpart Location	-
Palps	-
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	2 cerci
Comp. eye Size	Medium
Comp. Eye-Rel. Pos.	-
Antennae Type	Threadlike
Antennae Length	Long
Leg Characteristics	-
Tarsi	3 seg.
Characters ♀	-
Gen. Appearance	Large, slow, fly-like insects
Common Name	Stoneflies

PSOCOPTERA

Number of Wings	4,0
FW Description	Membranous, reduced venation
HW Description	Same
FW/HW	FW > HW
Wing Pos. at rest	Rooflike over body
Body Size	Small, 5 mm
Body Shape	-
Body Hardness	Soft
Body Pigment	-
Mouthparts	Chewing
Mouthpart Location	-
Palps	Developed
Head Characteristics	Bulging
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye Size	Small
Comp. eye-Rel. Pos.	-
Antennae Type	Hairlike
Antennae Length	Long
Leg Characteristics	-
Tarsi	2-3 Seg.
Characters ♀	-
Gen. Appearance	Very Small, gnat-like
Common Name	Book/Barklice

MALLOPHAGA

Number of Wings	0
FW Description	-
HW Description	-
FW/HW	-
Wing Pos. at Rest	-
Body Size	minute, < 5 mm
Body Shape	flattened d-v
Body Hardness	-
Body Pigment	light
Mouthparts	chewing
Mouthpart Location	H
Palps	-
Head Characteristics	Wider than thorax
Abdominal Shape	-
Abdominal Appendages	-
Comp. Eye Size	Small
Comp. Eye-Rel. Pos.	-
Antennae Type	3-5 seg.
Antennae Length	short
Leg Characteristics	1-2 claws
Tarsi	1-2 seg.
Characters ♀	-
Gen. Appearance	loose-like
Common Name	Chewing lice

ANOPLURA	
Number of Wings	0
FW Description	-
HW Description	-
FW/HW	-
Wings Pos. at Rest	-
Body Size	Minute
Body Shape	flattened d-v
Body Hardness	-
Body Pigment	-
Mouthparts	sucking
Mouthpart Location	H
Palps	-
Head Characteristics	narrower than thorax
Abdominal Shape	-
Abdominal Appendages	None
Comp. Eye Size	Small, absent
Comp. Eye-Rel. Pos.	-
Antennae Type	Threadlike tapering distally
Antennae Length	short
Leg Characteristics	1 large claw
Tarsi	1 seg
Characters	-
Gen. Appearance	louse-like
Common Name	sucking lice

THYSANOPTERA

Number of Wings	4,0
FW Description	Long, narrow, fringed, long hairs
HW Description	Same
FW/HW	1
Wings Pos. at Rest	-
Body Size	minute
Body Shape	-
Body Hardness	-
Body Pigment	pale bo black
Mouthparts	rasping/sucking
Mouthpart Location	chin
Palps	-
Head Characteristics	-
Abdominal Shape	tapering
Abd. Appendages	-
Comp. eye size	med.
Comp. eye-Rel. Pos.	-
Antennae Type	6-9 seg.
Antennae Length	short
Leg Characteristics	short
Tarsi	-
Characters	-
Gen. Appearance	small, with feather-like wings
Common Name	Thrips

NEUROPTERA	
Number of Wings	4
FW Description	Membranous, many veined
HW Description	cross veins, same
FW/HW	HW little larger at base
Wing Pos. at rest	roof-like over body
Body Size	large
Body Shape	long
Body Hardness	soft
Body Pigment	-
Mouthparts	chewing
Mouthpart Location	-
Palps	developed
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	cerci absent
Comp. eye size	small
Comp. eye-rel. pos.	-
Antennae Type	thread-like, clubbed, pectinate
Antennae Length	long, many seg.
Leg Characteristics	-
Tarsi	5 seg.
Characters	-
General Appearance	nerve winged flies
Common Name	Fishflies, snakeflies, lacewings, antlions

TRICHOPTERA	
Number of Wings	4
FW Description	Membranous, Hairy
HW Description	Membranous
FW/HW	FW > HW
Wing Pos. at rest	roof-like over body
Body Size	Small-Medium
Body Shape	Slender-elongate
Body Hardness	soft
Body Pigment	-
Mouthparts	sponging, reduced
Mouthpart Location	-
Palps	well developed
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Medium
Comp. eye-rel. pos.	-
Antennae Type	Threadlike
Antennae Length	Long as body or longer
Leg Characteristics	Long, slender
Tarsi	5 seg.
Characters	-
General Appearance	Mothlike
Common Name	Caddisflies

MECOPTERA

Number of Wings	4
FW Description	Membranous, cross veins
HW Description	spotted, transversely banded
FW/HW	FW = HW
Wing Pos. at rest	up and out
Body Size	small-medium
Body Shape	slender
Body Hardness	soft
Body Pigment	-
Mouthparts	chewing, prolonged into a snout
Mouthpart Location	a snout
Palps	developed
Head Characteristics	long faced
Abdominal Shape	-
Abdominal Appendages	male genitalia carried curved over back
Comp. eye size	medium
Comp. eye-rel. pos.	-
Antennae Type	threadlike
Antennae Length	1/2 body length
Leg Characteristics	long, slender
Tarsi	5 seg, 1-2 claws
Characters	-
General Appearance	Hanging flies
Common Name	Scorpionflies

LEPIDOPTERA	
Number of Wings	4
FW Description	Membranous, scaled
HW Description	Membranous, scalled
FW/HW	FW > HW
Wing pos. at rest	never folded
Body Size	Medium-large
Body Shape	thin
Body Hardness	soft
Body Pigment	-
Mouthparts	sucking proboscis
Mouthpart Location	H
Palps	Developed
Head Characteristics	-
Abdominal Shape	-
Abdominal appendages	-
Comp. eye size	Large
Comp. eye-rel. pos.	-
Antennae Type	Knobbed, plumose, slender
Antennae Length	Long
Leg Characteristics	-
Tarsi	-
Characters	-
General Appearance	Furry-slowflying, large wings
Common Name	Butterflies, Moths, Skippers

HEMIPTERA	
Number of Wings	4,0
FW-Description	Thick at base, membranous at tip
HW-Description	Membranous
FW/HW	FW > HW
Wing Pos. at rest	Folded over abd, FW tips overlapping
Body Size	-
Body Shape	-
Body Hardness	-
Body Pigment	-
Mouthparts	Sucking
Mouthpart Location	Arise from anterior of head
Palps	Lacking
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Large
Comp. eye rel. pos.	-
Antennae Type	5 seg or less
Antennae Length	Short-Concelaed, long-conspicuous
Leg Characteristics	-
Tarsi	3 or fewer segments
Characters	-
General Appearance	Many different varieties
Common Name	Bugs

HEMIPTERA

Number of Wings	4,0
FW Description	Thick at base, membranous at tip
HW Description	Membranous
FW/HW	FW > HW
Wing Pos. at rest	Folded over abd., FW tips overlapping
Body Size	-
Body Shape	-
Body Hardness	-
Body Pigment	-
Mouthparts	Sucking
Mouthpart Location	Arise from anterior of head
Palps	Lacking
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Large
Comp. eye rel. pos.	-
Antennae Type	5 seg or less
Antennae Length	Short-concealed, long-conspicious
Leg Characteristics	-
Tarsi	3 or fewer segments
Characters	-
General Appearance	Many different varieties
Common Name	Bugs

COLEOPTERA

Number of Wings	4
FW Description	Elytra-horny, meets in st. line down back
HW Description	Membranous
FW/HW	HW >> FW
Wing pos. at rest	HW folded to fanwise under elytra
Body Size	Minute to giant
Body Shape	Oval
Body Hardness	Hard
Body Pigment	-
Mouthparts	chewing
Mouthpart Location	H
Palps	Developed
Head Characteristics	-
Abdominal Shape	5 seg. (8)
Abdominal Appendages	-
Comp. eye size	Large
Comp. eye. rel. pos.	-
Antennae Type	Many types, 2-11 seg.
Antennae Length	Short-long
Leg Characteristics	-
Tarsi	3-5 seg.
Characters	-
General Appearance	Hard shelled, dark colored
Common Name	Beetles

HOMOPTERA	
Number of Wings	4,0
FW Description	Membranous or thickened
HW Description	Membranous
FW/HW	HW shorter than FW
Wing Pos. at rest	Roof-like over body
Body Size	Small to Medium
Body Shape	-
Body Hardness	-
Body Pigment	-
Mouthparts	Sucking
Mouthpart Location	Arising from back of head
Palps	Lacking
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Small to large
Comp. eye rel. pos.	-
Antennae Type	Long, thread-like; short, bristle-like
Antennae Length	Long, short, absent
Leg Characteristics	-
Tarsi	1-3 seg.
Characters ♀	Often has well developed ovipositor
General Appearance	Many different varieties
Common Name	Circadas, Hoppers, Aphids, scales, Whiteflies

DERMAPTERA

Number of Wings	4
FW Description	Thickened, Leathery, short
HW Description	Membraneous
FW-HW	-
Wing Pos. at rest	HW folded beneath FW
Body Size	Small-Medium
Body Shape	Flattened d-v
Body Hardness	Hard
Body Pigment	Dark
Mouthparts	Chewing
Mouthpart Location	H
Palps	-
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	Forceps-like cerci
Comp. eye size.	Medium
Comp. eye-rel. pos.	-
Antennae Type	Threadlike
Antennae Length	~ 1/2 body
Leg Characteristics	-
Tarsi	3 seg.
Characters	-
General Appearance	Beetle-like
Common Name	Earwigs

DIPTERA

Number of Wings	2
FW Description	Membranous
HW Description	Halteres
FW/HW	-
Wing Pos. at rest	flat,over abdomen
Body Size	Small-medium
Body Shape	-
Body Hardness	Medium soft
Body Pigment	-
Mouthparts	sucking
Mouthpart Location	-
Palps	Developed
Head Characteristics	Large eyes
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Large, Many faceted
Comp. eye-rel. pos.	Sometimes touching
Antennae Type	Variable, short 3 seg.
Antennae Length	Short
Leg Characteristics	Long
Tarsi	5 seg.
Characters ♂	-
Characters ♀	-
General Appearance	Fly-like
Common Name	Flies

SIPHONAPTERA

Number of Wings	0
FW Description	-
HW Description	-
FW/HW	-
Wing Pos. at rest.	-
Body Size	Small
Body Shape	Flattened Vent.
Body Hardness	Hard
Body Pigment	-
Mouthparts	Sucking
Mouthpart Location	-
Palps	Developed
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Small absent
Comp. eye-rel. pos.	-
Antennae Type	3 seg, fits into groves
Antennae Length	Short
Leg Characteristics	Coxae large, jumping
Tarsi	-
Characters	-
General Appearance	Small, jumping insects
Common Name	Fleas

HYMENOPTERA

Number of Wings	4
FW Description	Membranous, few veins
HW Description	Same
FW/HW	FW > HW
Wing pos. at rest	Over body
Body Size	Small-Medium
Body Shape	-
Body Hardness	Hard
Body Pigment	-
Mouthparts	Chewing, sucking structure
Mouthpart Location	-
Palps	Developed
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	Sting
Comp. eye size	Large
Comp. eye. rel. pos.	-
Antennae Type	bead
Antennae Length	Long
Leg Characteristics	-
Tarsi	5 seg.
Characters ♀	sting
General Appearance	hairless or fuzzy, buzzing insects
Common Name	sawflies, wasps, bees, ants

LEPIDOPTERA

Number of Wings	4
FW Description	Membranous, scaled
HW Description	Membranous, scaled
FW/HW	FW > HW
Wing pos. at rest	never folded
Body Size	Medium-large
Body Shape	thin
Body Hardness	soft
Body Pigment	-
Mouthparts	sucking proboscis
Mouthpart Location	H
Palps	Developed
Head Characteristics	-
Abdominal Shape	-
Abdominal Appendages	-
Comp. eye size	Large
Comp. eye-rel. pos.	-
Antennae Type	knobbed, plumose, slender
Antennae Length	Long
Leg Characteristics	-
Tarsi	-
Characters	-
General Appearance	Furry, slowflying, large wings
Common Name	Butterflies, Moths, Skippers